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A Retrospective Comparison of Military Health Surveillance Systems: An Example of Respiratory Illness at Marine Corps Recruit Depot (MCRD) San Diego

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Primary goals of health surveillance in the military include monitoring the health status of military personnel, and detecting outbreaks of naturally occurring and bioterrorism-related epidemics. Two near real-time automated surveillance systems currently in use by the Department of Defense (DoD) are the Medical Data Surveillance System (MDSS), and the Electronic Surveillance System for the Early Notification of Community-Based Epidemics (ESSENCE).

Both prototype systems are "passive" surveillance systems in that they use already collected diagnostic data reported as primary *International Classification of Diseases, 9th Revision* (ICD-9) codes on automated medical encounter records. The advantages of passive surveillance systems are many. These systems can rapidly detect unusual disease events, and a large number of individuals can be placed under surveillance. Passive systems impose no additional reporting burden on health care providers, and avoid the reporting bias inherent in non-automated surveillance systems. In contrast, traditional active surveillance (i.e., "hot pursuit") identifies cases by active searching and regular case reports from health care facilities. Although more expensive than passive surveillance, active surveillance data are usually considered more complete and accurate (Lilienfeld & Stolley, 1994).

Although MDSS and ESSENCE use the same source of data (i.e., primary ICD-9 codes entered into the Ambulatory Data System), they differ in their disease measures (i.e., reports), their assignment of ICD-9 codes into disease/syndrome categories, and their outbreak detection algorithms. Studies evaluating the impact of these methodological differences are few. Our previous research reported substantial differences between MDSS Version 3.1 and ESSENCE IB in their measures of respiratory illness, the number of ICD-9 codes used, the resulting number of cases captured, and leading diagnoses (Howe, Faix, Woodruff, & Kleiner, 2004). Interestingly, the differences did not appear to substantially alter conclusions about patient characteristics or at-risk groups. One unpublished retrospective study compared MDSS and ESSENCE detection of a *Streptococcus A* outbreak at San Diego clinics in 2002 (Melcer, 2003). Both systems generated outbreak alerts, although MDSS alerted earlier and was found to be more sensitive to changes. Another study examined the concordance between broad respiratory-related syndromic categories in ESSENCE and active surveillance of febrile respiratory illness (FRI) at 9 medical treatment facilities (Marsden-Haug, Elbert, Hawksworth, Foster, & Pavlin, 2002). ESSENCE was able to approximate the same FRI trends as the active surveillance system at several of the

facilities; however, as might be expected, ESSENCE counts were much higher than those identified by FRI-specific active surveillance.

The purpose of this paper was to add to the limited information about surveillance data using different mechanisms by retrospectively comparing the two systems' surveillance trends and potential outbreak detection of respiratory illness at the Marine Corps Recruit Depot (MCRD) San Diego. The choice of respiratory illness at MCRD for comparison is more than an academic one. The DoD is concerned about respiratory illness, including FRI, for several reasons. U.S. military populations have been subject to respiratory disease epidemics in the past, most notably during the influenza pandemic of 1918, when 43,000 U.S. troops died from the illness. Military personnel are deployed worldwide, often in areas that have a high prevalence of respiratory illness such as influenza. Also, the military population is highly mobile, providing opportunities to spread illness to a large number of people over a wide area. Respiratory illnesses have long been a problem particularly in recruit training camps, where close quarters facilitate rapid transmission.

In addition to the two passive automated systems, data were included from a third distinctly different type of surveillance system—traditional active surveillance of FRI at MCRD. Because all three systems have different case definitions and produce different disease measures, the systems were compared in a general way, focusing on patterns of change over time. Of primary interest was the comparison of the systems' respiratory illness trends and outbreak detection. In addition, we assessed the extent to which a passive system could capture the same trend as a traditional, active surveillance effort specifically monitoring FRI at MCRD.

Methods

Respiratory-related diagnoses were obtained retrospectively from MDSS Version 3.1, ESSENCE IV, and active FRI surveillance for the 64-week period of July 29, 2002, to October 19, 2003. Counts were used rather than rates because ESSENCE does not calculate rates. Weekly counts rather daily counts were compared because active FRI surveillance data are reported on a weekly rather than daily basis. All three systems (particularly MDSS and ESSENCE) may include follow-up visits in their weekly counts (our previous work has indicated that follow-up visits in the recruit population may be as high as 50%). MDSS and ESSENCE can distinguish between new and follow-up cases; however, their definitions of an initial versus follow-up visit

are quite different. Further, active FRI surveillance reporting does not allow for identifying new versus follow-up visits. For this reason, *total* counts are used from all systems. Occasionally a nonrecruit may be treated at the MCRD clinic, and MDSS and ESSENCE will include these cases. However, these cases are few, and because our primary question is how well the systems can easily reflect respiratory illness without additional analysis for selecting certain cases, data were used as is without removing nonrecruits.

MDSS and ESSENCE each have multiple respiratory-related automated reports. Three reports from MDSS and two from ESSENCE were included (see below), in addition to results from active FRI surveillance.

Description of MDSS

MDSS, developed by the Naval Health Research Center (NHRC) and the Space and Naval Warfare Systems Command San Diego, is a Web-based medical surveillance system that provides near real-time medical threat assessment using routinely collected medical data. MDSS is currently being used to monitor illness trends and potential epidemics at medical treatment facilities (MTFs) (hospitals and clinics) in the San Diego area. Data come from the DoD Standardized Ambulatory Data Record (SADR), records that are designed primarily for health care management and cost monitoring. For every outpatient encounter within the DoD, a SADR is produced and coordinated with some patient demographic data on a daily basis. Data include visits by active-duty personnel and their families as well as retirees and other non-active-duty beneficiaries. The SADR is usually completed at the place and time of the patient encounter. The provider completes the SADR with a known or presumed diagnosis from the ICD-9. Within MDSS, ICD-9 codes are grouped into several broader reports, including the Disease and Non-Battle Injury (DNBI) report. DNBI categories include Total Respiratory visits, as well as Lower and Upper Respiratory visits. MDSS provides counts as well as rates for each of the MTFs.

Among its monitoring capabilities, MDSS applies a Dynamic Change-point Detection (DCD) algorithm to quickly detect significant increases in disease trends. The DCD employs the Shewhart test, as well as an extended cumulative sum (CUSUM) method, methods commonly used in industry to detect unwanted changes in industrial processes. CUSUM methods operate by accumulating deviations between observations and expectations. When cumulated deviations exceed some predefined threshold, an alarm or alert is generated, indicating an increase in the mean of the underlying condition. DCD can detect different degrees of outliers (i.e., shifts,

trends). In the present study, we focused on the most extreme statistical event (i.e., burst), a data point 3 or more standard deviations away from the mean. The MDSS Reference Manual provides more detail and a mathematical description of the DCD algorithm (Pugh, 2003).

Description of ESSENCE

ESSENCE, developed by the DoD Global Emerging Infections System at Walter Reed Army Institute of Research, was designed for early discovery of infectious disease outbreaks at MTFs and in the civilian sector. Like MDSS, ESSENCE pulls SADR outpatient data on a daily basis, and categorizes ICD-9 codes into broader groupings. While MDSS pulls SADR data directly from servers at local MTFs, ESSENCE is a DoD-wide system that pulls data from a central TRICARE server. Seven preset ESSENCE syndrome groupings focus on infectious disease. Two ESSENCE syndrome groupings are included in this study. The first is the ESSENCE Respiratory Syndrome that includes specific and nonspecific diagnoses and symptoms of acute respiratory tract infections, while excluding chronic conditions such as bronchitis and asthma. The second ESSENCE syndrome included is the Febrile Illness Syndrome, a fairly broad category that captures febrile conditions with both unknown and specific causes.

Two other ESSENCE categories, DNBI Total Respiratory and Influenza-like Illness (ILI), were considered for inclusion in the comparison, but were not used. ESSENCE DNBI Total Respiratory was so highly correlated with ESSENCE Respiratory Syndrome (r = .99), it was considered redundant. Also, ESSENCE detection algorithms are not run on the DNBI data. ILI within ESSENCE is measured as a percentage of total visits (versus actual counts) and is presented for all San Diego MTFs combined; therefore, it was not included in this comparison of MCRD-specific respiratory conditions.

For detecting potential outbreaks in ESSENCE IV, a prediction of normal daily ranges for the syndrome group is done using historical data. Regression models base daily predictions on an empirically derived baseline period covering between 4 and 12 weeks of ESSENCE data. Confidence intervals are fitted around predicted daily counts, and the upper bound is used as a threshold. Numbers of daily patient encounters that fall outside the confidence interval indicate a departure from the values that are expected. If the observed count exceeds the 99% confidence interval, it is considered to be a high-level warning. (See https://essencewww.jhuapl.edu/jsipp/servlet/HomePageServlet for more in-depth information

about ESSENCE and its outbreak detection algorithms. A user ID and password must first be acquired and can be requested at Essence@deploymenthealth.osd.mil).

Description of Active FRI Surveillance

Active FRI surveillance is ongoing at MCRD San Diego and 7 other U.S. military training sites to provide an early warning system for detection of potential FRI epidemics in the recruit population. Rather than identifying cases from ICD-9 codes in automated medical records, trained personnel at MCRD actively monitor their training population for FRI. Active-duty trainees who visit the clinic with an oral temperature of 100.5^{o}F or higher, and who have a respiratory symptom such as a cough or sore throat, are counted as FRI cases. In addition, any trainee diagnosed with pneumonia is considered a case of FRI. MCRD reports its FRI counts and population numbers to investigators at the NHRC *on a weekly basis*, who then publish weekly FRI rates on the Internet for rapid dissemination of information.

For detection of potential outbreaks, NHRC classifies the MCRD weekly FRI rate into one of three status categories: (a) at or below an expected value, (b) moderately elevated, or (c) substantially elevated. A combination of fixed and variable alarm thresholds are used to determine FRI rate status. Fixed thresholds are generated based on the 90th and 95th percentiles of their past rates. Variable thresholds are calculated using autoregressive integrated moving average (ARIMA) modeling. In the case of differences in the fixed and variable status, the more extreme FRI rate status is used for that week's classification. More information about FRI surveillance at MCRD can be found at http://www.nhrc.navy.mil/geis/.

Analysis

Analyses are descriptive and correlational. Averages (means or medians) are used to describe characteristics and surveillance results from the three systems' various reports, including the average weekly number of cases captured. Weekly counts of respiratory-related illness and system outbreak alerts are presented graphically. Pearson correlations are used to examine the associations between the three systems' counts and alerts.

Results

ICD-9 Coding Differences in MDSS and ESSENCE

Table 1 presents the number of ICD-9 codes used by MDSS and ESSENCE in their various respiratory-related reports. While ESSENCE codes focus on infectious illnesses, MDSS coding reflects both infectious and chronic respiratory conditions. MDSS uses more ICD-9 codes for its Total Respiratory report than the broadest ESSENCE report, Respiratory Syndrome (209 vs. 137 ICD-9 codes). ESSENCE Respiratory Syndrome report typically categorized more cases than MDSS (mean of about 180 cases per week vs.160 cases per week; median of 127 vs. 88 cases per week). The ESSENCE Febrile Illness Syndrome report had few cases over the surveillance period, with a median weekly number of 0 (mean = 2.6). Cases reported by active FRI surveillance was relatively low, with a median of 13 cases per week (mean = 16). Typically, MDSS and ESSENCE had the same leading diagnoses: 465.9 (Acute upper respiratory infections of multiple or unspecified sites), 466.0 (Acute bronchitis or bronchiolitis), and 486 (Pneumonia, organism unspecified).

Comparison of Respiratory Illness Trends

Figure 1 presents the weekly number of cases reported by each surveillance system over the 64-week period. As described in the Methods, 3 reports are shown from MDSS–DNBI Total Respiratory, DNBI Upper Respiratory, and DNBI Lower Respiratory. Due to technical difficulties, MDSS failed to collect data for the period of September 30 through October 13, 2002, therefore no data are reported from MDSS for those 2 weeks. Two reports from ESSENCE are presented—Respiratory Infectious Disease Syndrome and Febrile Illness Syndrome. The thin solid line represents cases identified through active FRI surveillance at MCRD.

ESSENCE Respiratory Syndrome usually reported the most cases per week, followed closely by cases reported by MDSS Total Respiratory. ESSENCE Respiratory Syndrome, MDSS Total Respiratory, and MDSS Upper Respiratory counts showed a similar pattern of increases and decreases week to week. Not surprising, trends in the number of cases appearing in the MDSS Lower Respiratory report were somewhat independent of MDSS Total and Upper Respiratory trends. As one would expect, the numbers of FRI cases identified through active surveillance were relatively low, ranging from 1 to 50 per week (median of 13 and mean of 15.5

cases per week). The number of cases from the ESSENCE Febrile Illness Syndrome report also was low, ranging from 0 to 42 cases per week, with over half of the weeks showing 0 cases.

Table 2 presents Pearson correlations for the systems' various reports. Weekly counts captured by the MDSS Total Respiratory report were very highly correlated with ESSENCE's Respiratory Syndrome (r = .985). MDSS Upper Respiratory and Lower Respiratory counts also were highly correlated with ESSENCE Respiratory Syndrome (.81-.90). ESSENCE Febrile Illness Syndrome was not strongly related to any other report, including active FRI surveillance. Active FRI surveillance was most strongly associated with MDSS Upper Respiratory (.62), closely followed by ESSENCE Respiratory Syndrome (.57), and MDSS Total Respiratory (.56).

Potential Outbreak Detection

Although MDSS and ESSENCE collect data and issue alerts of significantly increasing trends on a *daily* basis, active FRI surveillance at MCRD aggregates data and issues alerts based on weekly data. Therefore, alert information is presented on a weekly basis for comparison purposes. Table 1 presents the number of weeks during the 64-week surveillance period that each system generated at least one alert. Figure 2 shows the information graphically by week with symbols corresponding with the patient visit counts. The MDSS Total Respiratory report produced at least one alert in 39 of the 64 weeks (61% of all weeks); MDSS Upper and Lower Respiratory reports produced even more alerts (63-65% of weeks). These numbers are in sharp contrast to the 11 alerts issued by ESSENCE Respiratory Syndrome (17% of all weeks). The ESSENCE Febrile Illness Syndrome alerted only 3 of the 64 weeks. Active FRI surveillance at MCRD produced alerts for 22 of the 64 weeks (34%), with most of the alerts occurring in the final weeks of the surveillance period. Pearson and Spearman correlation coefficients computed for (a) the number of alerts per week, and (b) the presence (yes vs. no) of *any* alert during the week confirmed relatively low associations among MDSS, ESSENCE, and active FRI surveillance systems (r = .05-.28).

Considering number of alerts on a *daily* basis for MDSS and ESSENCE, MDSS produced many more alerts than did ESSENCE (see Table 1). About 20% (n = 80-90) of the 448 days of the surveillance period showed an alert by one or more of the MDSS various respiratory reports, compared with 3% (14 days) by the ESSENCE Respiratory Syndrome report.

A known outbreak of *Streptococcus A* the second week of December 2002 was used to assess if and how rapidly the systems alerted. Active FRI surveillance generated an alert for that

week, but because active surveillance results are only reported weekly, daily data are not available. MDSS and ESSENCE, on the other hand, gather data and create reports on a daily basis; therefore, they were compared to assess how quickly each alerted that week. The MDSS Total Respiratory report produced an alert on December 11, with many of the cases diagnosed as possible *Streptococcus A* infection. ESSENCE's Respiratory Syndrome alerted on December 14.

Discussion

Despite differences in ICD-9 code categorization methods and resulting disease measures, automated reports generated by MDSS 3.1 and ESSENCE IV showed similar trends in respiratory illness at MCRD San Diego over a 64-week period. In particular, the systems' broadest respiratory reports, MDSS Total Respiratory and ESSENCE Respiratory Syndrome, showed similarity in the numbers of respiratory cases, and changes over time. There was a very high correlation between these two reports (.98), although there was variability in the correlations among some of the other automated reports. For example, ESSENCE Febrile Illness Syndrome showed very low counts and low correlations with other automated respiratory measures, including FRI counts captured through active surveillance. It may be that the particular ICD-9 codes ESSENCE uses for its Febrile Illness Syndrome are either rare conditions (e.g., Plague–020.0), or rarely assigned as a primary diagnosis (e.g., Fever–780.6).

The MDSS Total Respiratory and Upper Respiratory reports and ESSENCE's Respiratory Syndrome were also somewhat successful in reflecting respiratory illness trends from a distinctly different type of surveillance system—traditional active surveillance of FRI. Not surprising, MDSS and ESSENCE counts of respiratory illness were much higher than FRI counts from active surveillance, most likely because their respiratory categories use a relatively large number of ICD-9 codes, many of which are not related to FRI. Despite that, correlations between active FRI surveillance and the automated diagnoses-based systems ranged from .56-.62, indicating fairly high correlations of their counts.

While *counts* were relatively highly correlated among the systems (depending upon the report), number and presence of alerts generated by the systems were not highly related. The broadest MDSS report alerted about 61% of all weeks, ESSENCE alerted 17% of all weeks, and active FRI surveillance was intermediate, alerting 34% of all weeks. Although ESSENCE was much more parsimonious in its outbreak alerts, MDSS indicated a later-confirmed outbreak a

few days earlier than did ESSENCE. Users' reports of MDSS sensitivity has been has been reported elsewhere (Melcer, 2003). While some view the relatively high sensitivity to change of MDSS as a strength, others consider it a drawback because of the resources and time needed to further investigate each alert, and because of the likelihood of false alarms. The optimal level of sensitivity of a system probably differs depending on the needs and interest of the user.

Limitations

One limitation in this comparison study was the inability to match individual patient records across the systems to determine the extent to which the same individuals were "captured." Although the three systems use overlapping patient populations (i.e., outpatient visits at the MCRD clinic), a common identifier did not exist. In addition, patient population characteristics (e.g., age, sex) are not readily available for all three systems; therefore, it was not possible to confirm the similarity of the patient populations. Furthermore, there are likely inaccuracies in the data (e.g., underreporting of cases from active FRI surveillance, nonstandardized ICD-9 coding in MDSS and ESSENCE), the extent of which is not known. A comparison of initial cases (rather than total) would have been valuable, but was not done because of the systems' inconsistent definitions of incidence. Finally, generalizability of these results to other populations and other medical conditions cannot be assumed.

Differences in disease measures make comparisons between the two automated surveillance systems and active surveillance results difficult. There is no system or measure in the present study that could be considered a gold standard; therefore, we cannot recommend one system, or report within a system, as superior. In fact, all three systems included seem to each have their specific strengths and shortcomings.

Conclusions

MDSS and ESSENCE measures, particularly their broadest respiratory-related reports, appear to be useful tools for surveillance of respiratory illness in recruits. The basis of these two systems, ICD-9 codes, often reflect unconfirmed diagnoses and nonspecific symptoms. Therefore, passive surveillance systems will not replace more traditional surveillance and public health reporting systems. However, because these systems are far less resource intensive, and

reasonably reflect disease trends, they may be valuable adjuncts for surveillance of other medical conditions and populations.

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Table 1. Number of ICD-9 Codes Used, Average Weekly Number of Cases, and Number of Alerts Issued, by Surveillance System — MCRD San Diego, 29 July 2002–19 October 2003

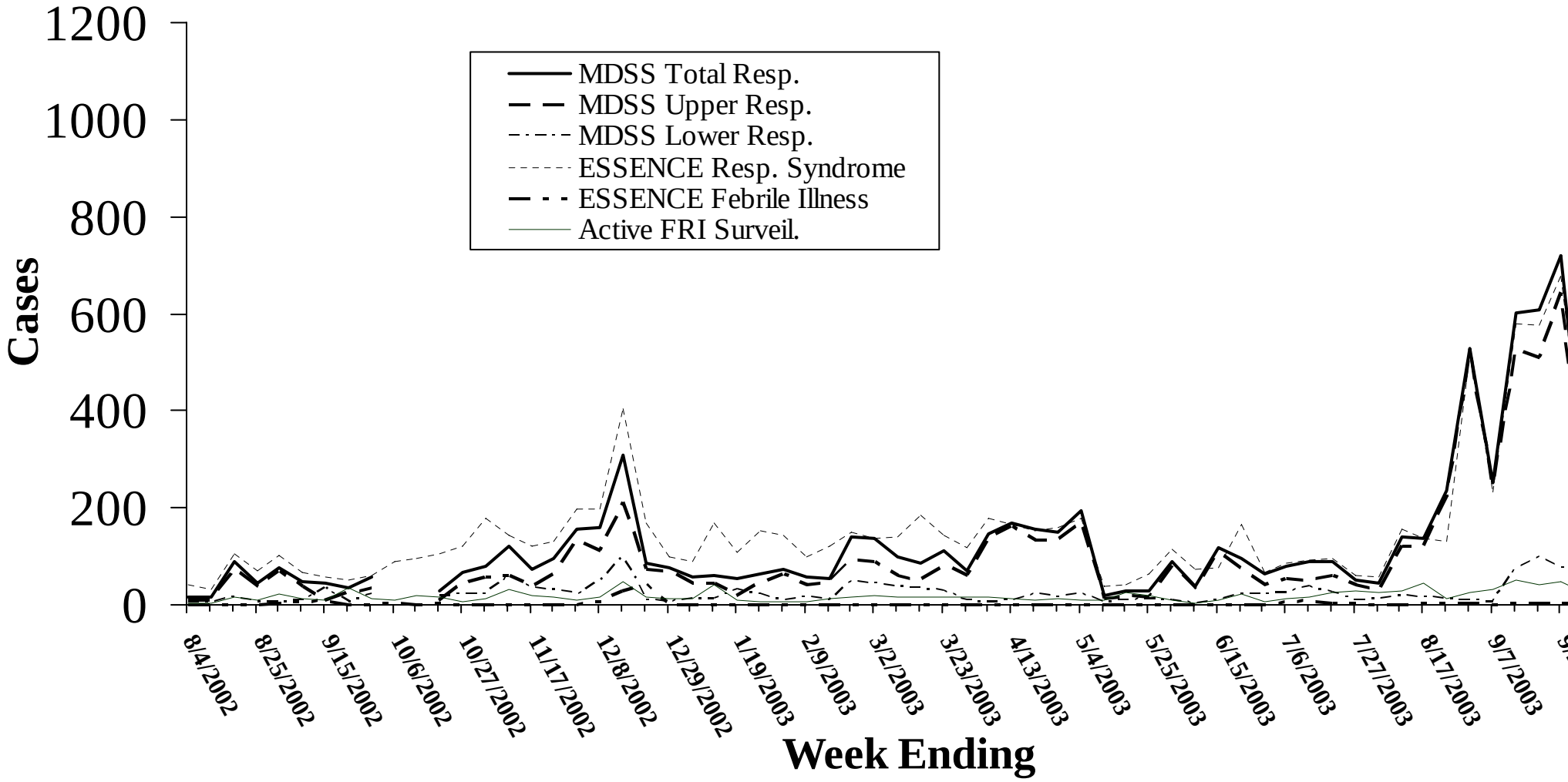
	Surveillance System/Report					
	MDSS Total Resp	MDSS Upper Resp	MDSS Lower Resp	ESSENCE Resp Synd	ESSENCE Febrile Ill. Synd	Active FRI Surveill
No. of ICD-9 codes used by system	209	81	128	137	114	N/A
Number of weekly cases (median)	87.5	62.5	43.7	126.5	0.0	13.0
Number of weekly cases (mean)	159.9	116.2	19.0	180.2	2.6	15.5
Number of weeks with at least one alert	39	42	40	11	3	22
Days alerted	90	80	90	14	3	N/A

Table 2. Pearson Correlation Coefficients for Surveillance Systems' Weekly Counts of Respiratory-related Illness — MCRD San Diego, 29 July 2002–19 October 2003

	Surveillance System/Report					
	MDSS Total Resp	MDSS Upper Resp	MDSS Lower Resp	ESSENCE Resp Synd	ESSENCE Febrile Ill. Synd	Active FRI Surveill
MDSS Total Resp	1.00					
MDSS Upper Resp	.895**	1.00				
MDSS Lower Resp	.806**	.458**	1.00			
ESSENCE Resp Synd	.985**	.864**	.818**	1.00		
ESSENCE Febrile Ill. Synd	.097	.095	.067	.139	1.00	
Active FRI Surveillance	.561**	.623**	.291*	.569**	.197	1.00

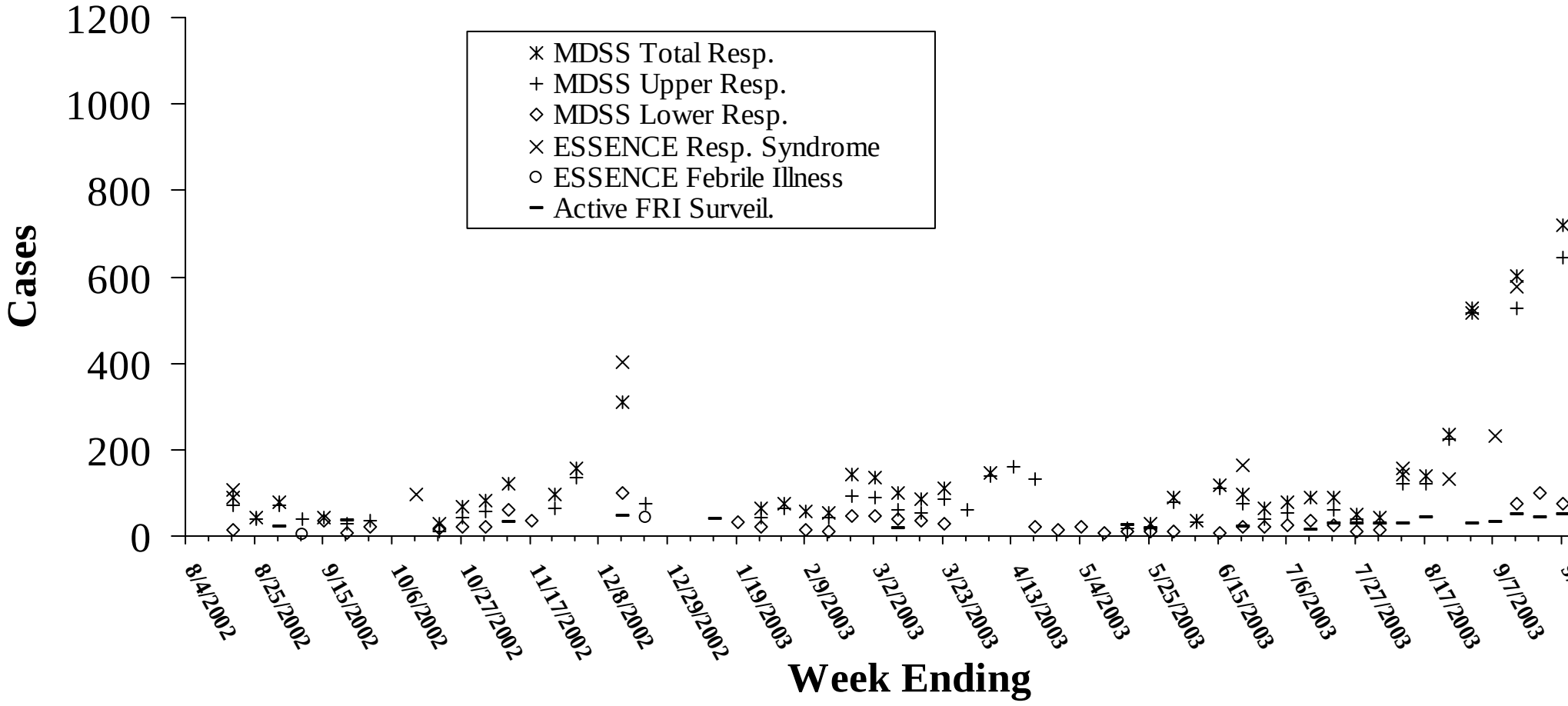
*Correlation is significant at the .05 level (2-tailed).
**Correlation is significant at the .01 level (2-tailed).

Figure 1. Counts of Respiratory-related Illness from MDSS, ESSENCE, and Active FRI Surveillance, by week -- MCRD San Diego, 29 July 2002-19 October 2003



Note: MDSS missing data for 2-week period of 9/30-10/13, 2002.

Figure 2. Alerts of Increasing Respiratory-related Illness from MDSS, ESSENCE, and Active FRI Surveillance, by week -- MCRD San Diego, 29 July 2002-19 October 2003



Note: MDSS missing data for 2-week period of 9/30-10/13, 2002.

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14. ABSTRACT (maximum 200 words)

Primary goals of health surveillance in the military include monitoring the health status of military personnel, and detecting outbreaks of naturally occurring and bioterrorism-related epidemics. Two near real-time automated surveillance systems currently in use by the Department of Defense are the Medical Data Surveillance System (MDSS) and the Electronic Surveillance System for the Early Notification of Community-Based Epidemics (ESSENCE). Both prototype systems are "passive" surveillance systems, using already collected diagnostic data reported as primary ICD-9 codes on automated medical encounter records. Although MDSS and ESSENCE use the same data source (i.e., ICD-9 codes entered into the Ambulatory Data System), their assignment of ICD-9 codes into disease/syndrome categories differs, and each system uses a different outbreak detection algorithm. The purpose of this retrospective research was to compare the two systems' surveillance trends and potential outbreak detection of respiratory illness at the Marine Corps Recruit Depot (MCRD) San Diego, over the 64 weeks of July 29, 2002, to October 19, 2003. For additional comparison, data from traditional active surveillance of febrile respiratory illness (FRI) conducted on-site at MCRD are also included. Results of the present study describe counts of respiratory illness captured by MDSS and ESSENCE and active FRI surveillance, as well as each system's outbreak detection performance.

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